GREEN AND GREY: THE POSSIBILITY OF COMBINING GREEN INITIATIVES WITH WATER REUSE

Samantha van Staden

University of Johannesburg, Dept. Civil Engineering Science, PO Box 524, Auckland Park 2006, South Africa, Tel: +27 11 559 2395, Cell: +27 82 924 3488, E-mail: samvs@uj.ac.za.

Abstract

As water scarcity becomes a bigger issue in South Africa so does the need for water saving practices. Couple this with the push to 'green' our cities and you get an interesting and, what some may consider, complex situation. As Water Scientists we are greatly positioned to provide direction towards solving this situation.

More and more we are hearing about greywater reuse, especially it's very real advantages in terms of irrigation, and, thereby, water savings (Jacobs and Van Staden, 2008; Van der Walt, 2012; Gouveia, 2013; Ilemobade *et al.*, 2013; Van der Walt, 2013; Natha, 2015). In addition, more research is being performed on the use of greenroofs on a residential level (Van der Walt, 2013; Baloyi, 2014; Padiachy, 2014; Borchers *et al.*, 2015).

The Water Research Group of the University of Johannesburg has been performing a combination of these research areas since 2012 and have, thus far, obtained interesting results that have been used, in conjunction, to better understand the possibilities of the use of these two systems.

Media choice

Van der Walt (2013) investigated the suitability of growth media for the use on 'flat' (3° incline) greenroofs in South Africa and irrigated said greenroofs with greywater obtained from a student residence at the University (Ilemobade *et al*., 2013).

This investigation focused on water retention and attenuation through moisture content readings and volume passed through the roof over time.

Summing up her results, it was shown that, of the three growth media investigated, vermiculite, in conjunction with compost and potting soil (in a 1:1:1 ratio), was the best water retaining option for a residential 'flat' greenroof (as shown in figure 1 below). Vermiculite was shown to have properties such as a high absorptive ability, neutral pH, good pH buffering capacity and a low infiltration rate of 1-5 mm/h which makes it suitable for retention and attenuation of water.

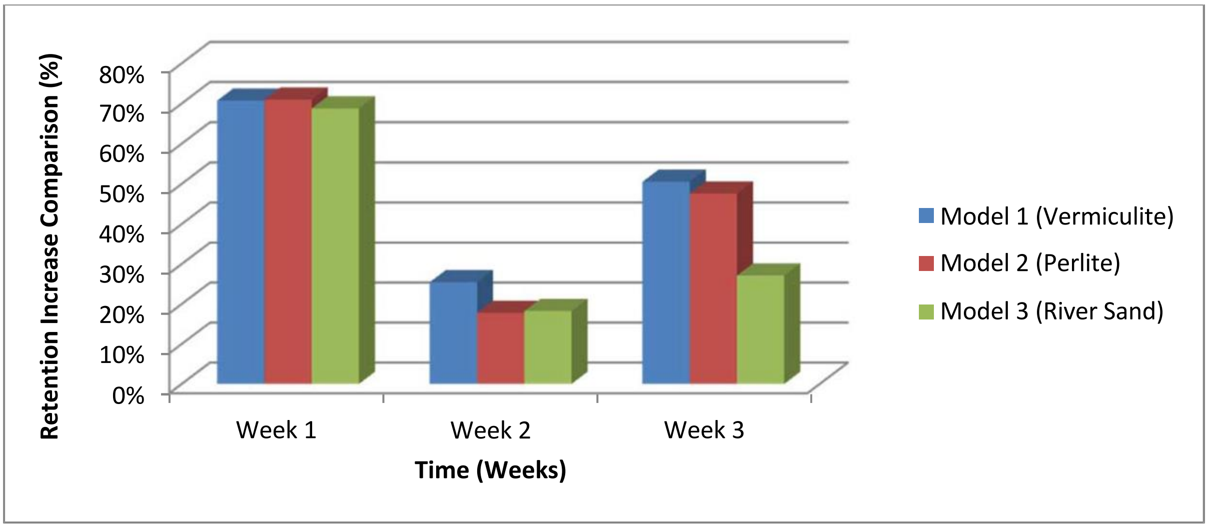

Figure 1: Percentage Retention Comparison of Models 1-3 to Model 4 (Control).

NOTE: The vegetation grown on all three models was Mexican Rosettes (*Echevaria sp.*), i.e. succulents.

In figure 2 below, the design of the greenroof models is shown in more detail (adapted from http://www.greengarage.ca/greenroofs/features.php).

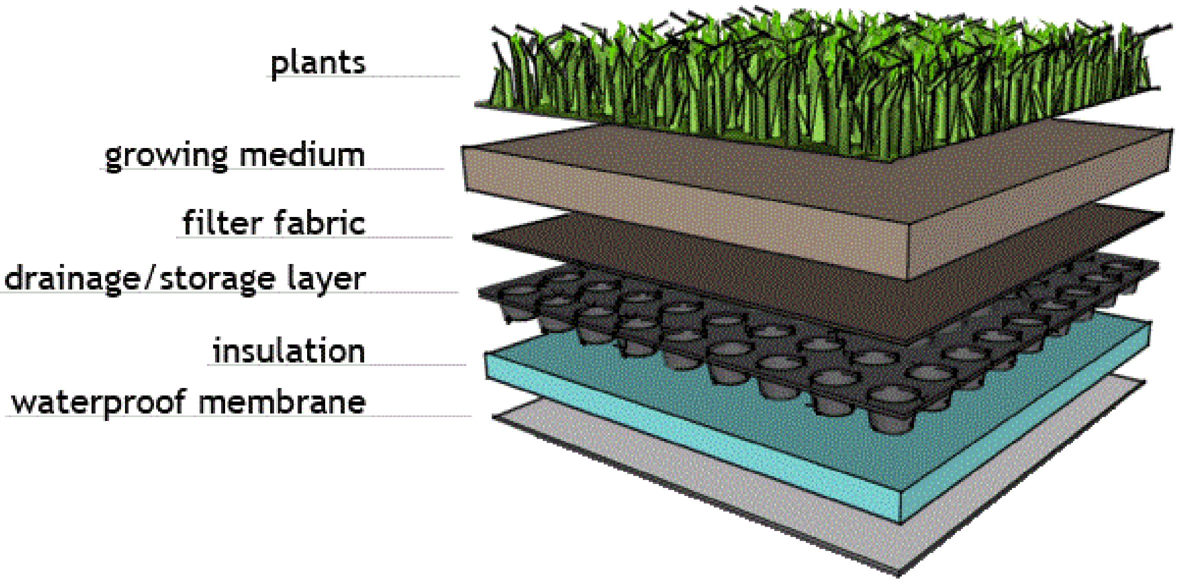

Figure 2: Exploded view of a typical greenroof and its layers.

Vegetation Type

Malatji (2014), following on from Van der Walt (2013), investigated the difference between vegetation types, specifically whether there was a difference in water retention and attenuation when comparing a sparse vegetation type (Mexican Rosettes – *Echevaria sp.*) with a dense vegetation type (Grass – *Kikuyu sp.*), again via moisture content readings and volume passed through the roof over time. Unfortunately, this study ran into some issues that made the results unreliable and, as a result, the only information that really came out of this study was that grass alone could indeed be used as a vegetation option on greenroofs and that, its growth and health was subject to the watering regime employed.

Greenroof Application on Varying Inclined Roof Structures

A study undertaken by Baloyi (2014) looked into whether a greenroof could be used on an inclined surface (two inclinations used: 22° and 45°) versus a 'flat' surface (3° inclination) as illustrated in figure 3 below (from Baloyi, 2014). This study adopted the findings of Van der Walt for its use of growth media, i.e. vermiculite, potting soil and compost in a 1:1:1 ratio, as well as using greywater for the irrigation of all the greenroofs for the duration of the study.

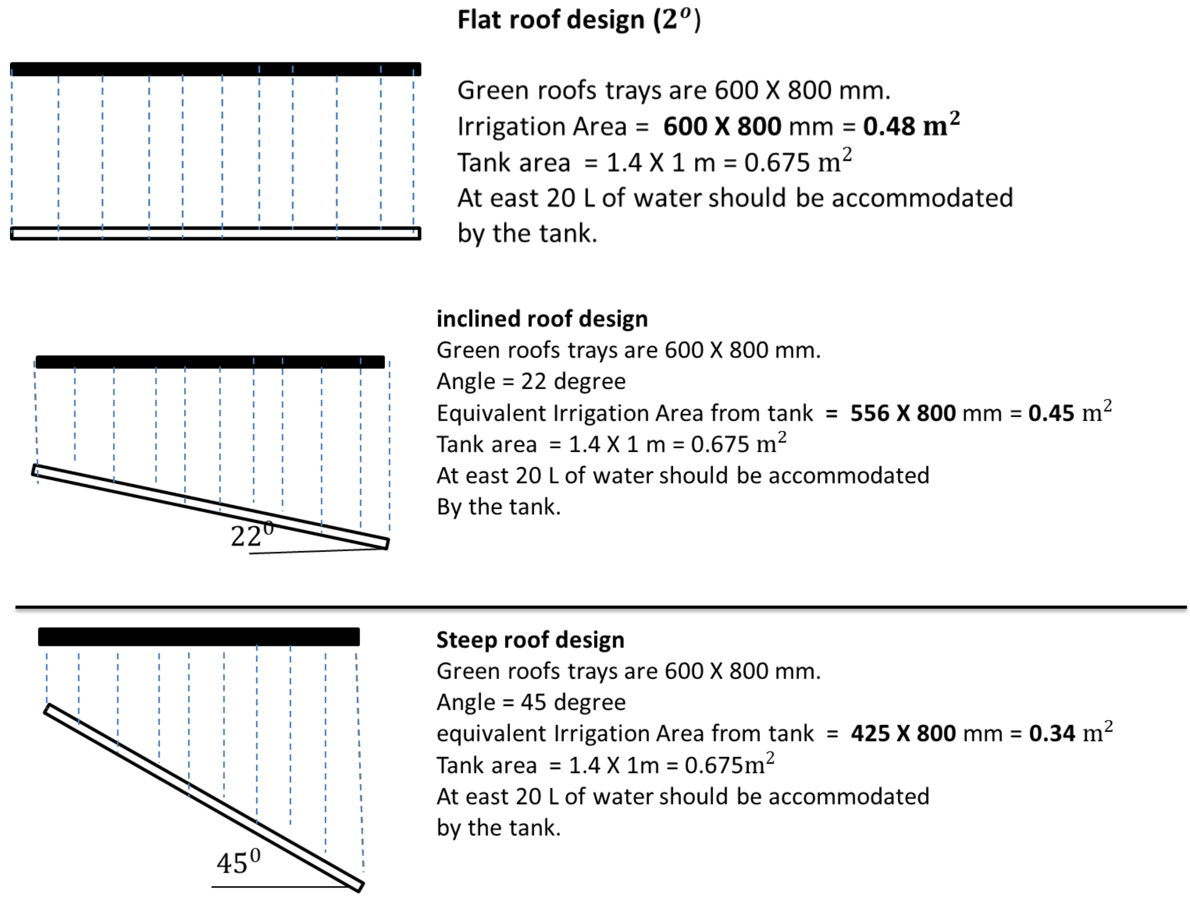

Figure 3: Experimental set- up of inclined surfaces (Baloyi, 2014).

As was expected, the 'flat' greenroof was more effectual that the inclined greenroofs in terms of water retention and attenuation. The most interesting result, however, was that the 22° inclined greenroof was more effectual than the 45° inclined greenroof and, in some cases (when assessing individual water events), could be as effectual if not more so than the 'flat' roof in terms of water retention and attenuation (table 1 below). These results also found that water retention and attenuation of a greenroof was dependant on the intervals of the watering events, i.e. high moisture content of the growth medium in the 'flat' roof rendered it less effectual at retention and attenuation than a 22° inclined greenroof with high moisture content (see results in table 2 below).

Table 1: Individual retention and attenuation of greenroofs at different inclinations.

	Run off collected		
Runoff interval	**Flat roof 3° (ℓ)**	**Inclined 22° (ℓ)**	**Inclined 45° (ℓ)**
0	0.00	0.00	0.00
1 min	1.64	2.76	4.18
5 min	3.96	1.30	1.04
15 min	0.66	0.30	0.20
30 min	0.06	0.02	0.002
1 hour	0.001	0.02	0.002
24 hours	0.00	0.00	0.00
Runoff time (s)	58	30	31
pH	8.5	8.5	8.0
Moisture content	8.0	1.0	3.0
Total water released (ℓ)	6.32	4.40	5.42
Initial amount of water (ℓ)	10	10	10
Amount retained (ℓ)	3.68	5.60	4.58
Percentage retention (%)	36.8	56.0	45.8
NOTE: Test performed in week 5, 2nd watering event of the week.			

Table 2: Average retention and attenuation of greenroofs at different inclinations.

	Run off collected		
Runoff interval	**Flat roof 3° (ℓ)**	**Inclined 22° (ℓ)**	**Inclined 45° (ℓ)**
0	0	0	0
1 min	0.437	1.978	3.522
5 min	1.262	1.043	0.932
15 min	0.949	0.404	0.174
30 min	0.183	0.115	0.065
1 hour	0.041	0.074	0.028
24 hours	0.008	0.022	0.006
Runoff time (s)	111.733	24.333	17.217
pH	8.25	8.5	8.25
Moisture content	5	1.375	2.05
Total water released (ℓ)	2.880	3.636	4.725
Initial amount of water (ℓ)	10	10	10
Amount retained (ℓ)	7.120	6.364	5.275
Percentage retention (%)	71.202	63.638	52.747

Greywater quality tests

Through water quality testing (see list of parameters tested for in table 3 below), Padiachy (2014) determined to what extent a greenroof can be used as a 'natural wetland' to filter and 'clean' greywater, i.e. its natural filtration capability, and whether a greenroof could be used to improve water quality to an acceptable level before it enters the stormwater system, thereby, minimising treatment costs down the line.

Table 3: Water quality parameters measured during Padiachy (2014) study.

Parameter	**Measurement Method**
Nitrogen (N)	Measured as Nitrate and Nitrite (*colorimetric/spectrophotometric method*)
Phosphorus (P)	Measured as Phosphates (*colorimetric/spectrophotometric method*)
E.coli	Measured using Colilert®-18 (*most probable number method*)
Faecal Coliforms	Measured using Colilert®-18 (*most probable number method*)
Total Coliforms	Measured using Colilert®-18 (*most probable number method*)

It was expected that the quality would be improved. However, testing indicated that this was rarely the case (see figures 4 – 8 below, from Padiachy, 2014).

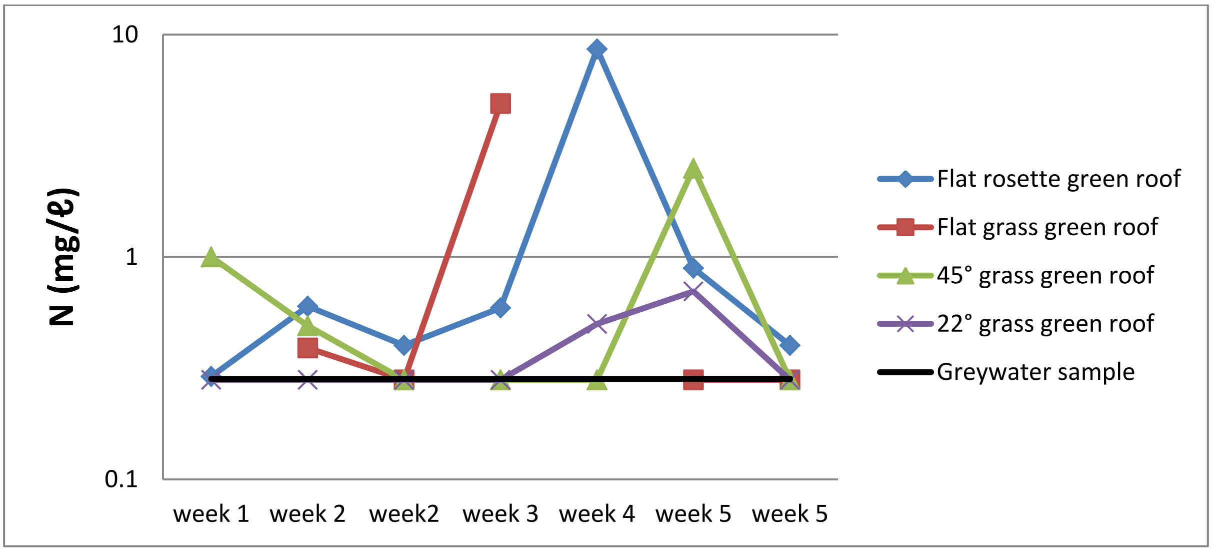

Figure 4: Combined nitrate and nitrite levels (as N) of greywater runoff samples collected from four greenroofs, with typical greywater N level included for comparison.

According to the WRC (1998), nitrogen levels of <6 mg/ℓ are ideal for all types of water use, whilst levels between 6 and 10 mg/ℓ are still considered good, with insignificant risk for drinking and food preparation purposes.

From this point of view, despite this quality parameter being higher than that of the greywater, it is still within an acceptable range.

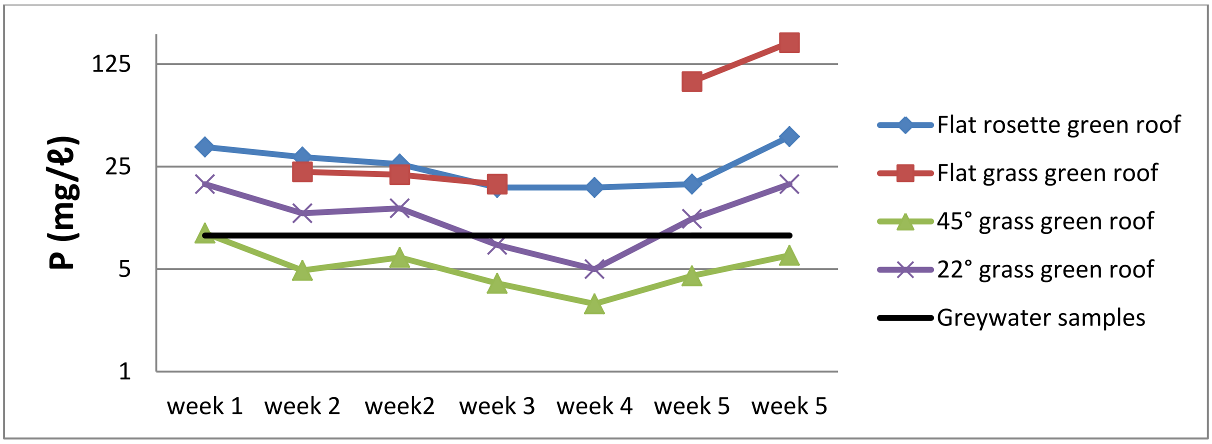

Figure 5: Phosphorus levels (as P) of greywater runoff samples collected from four greenroofs, with typical greywater P level included for comparison.

No ideal levels for phosphorus is found in either the WRC (1998) or the SANS 241:2011. However, Moran *et al*. (2004) found that total phosphorus in greenroof run-off occurred and argue that this may have arisen from the high organic matter present in the compost within the growth medium.

From this point of view, the P levels from this study were, most often, increased from the greywater level. However this was not always the case, especially with the 45° inclined roof, perhaps due to the low water retention ability of this greenroof.

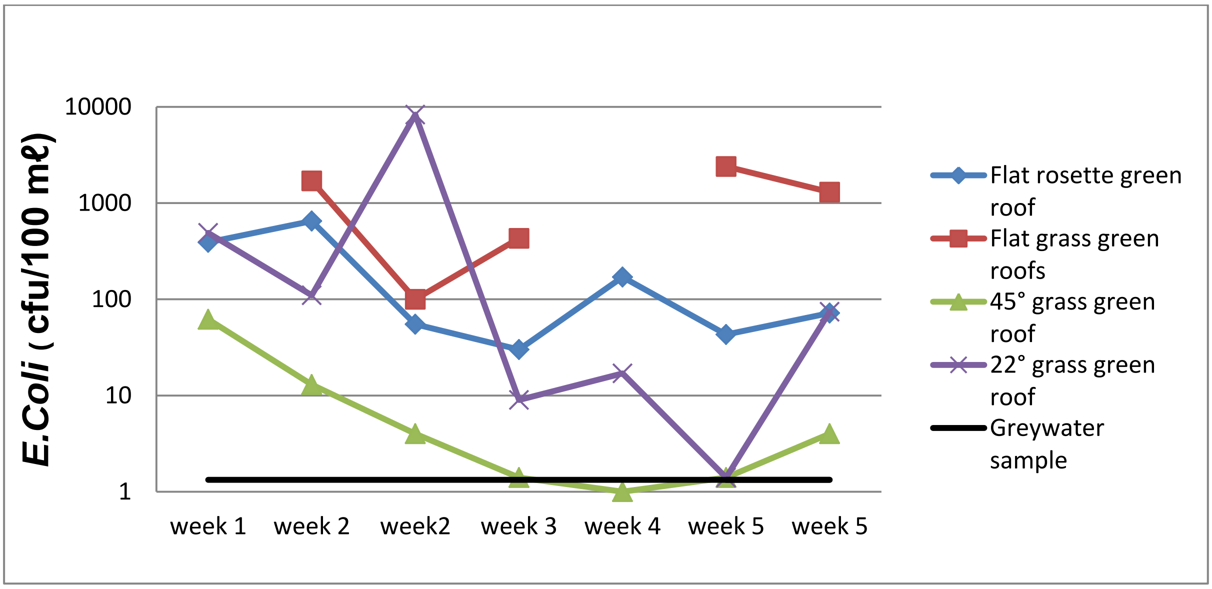

Figure 6: *E.coli* levels (cfu/100 mℓ) of greywater runoff samples collected from four greenroofs, with typical greywater *E.coli* level included for comparison.

The WRC (1998) and the SANS 241:2011 do not list E.coli separately, but as a part of faecal coliforms. 0-1 cfu/ 100 mℓ is listed as ideal or good levels, with no effects or an insignificant chance of infection. Clearly from both figures 6 and 7, these levels are unacceptable in both cases, being greater than even the greywater levels (in both cases >1 cfu/100 mℓ). Only in the case of the 45°

inclined greenroof do we see these levels decrease on one occasion for *E.coli* results, as compared with the greywater. In general, the results show an increase in these levels, therefore suggesting that there is a contributing factor within the greenroof set-up to these levels. The 'tanks' used to water the greenroofs were also left standing and faecal matter may have found its way into the greenroof through irrigation from these tanks. To better test which scenario is most likely, research is currently being performed to determine the degree of contribution from the above-mentioned scenarios, as well as to determine if a flushing period could be used and, thereby, improve the water quality thereafter.

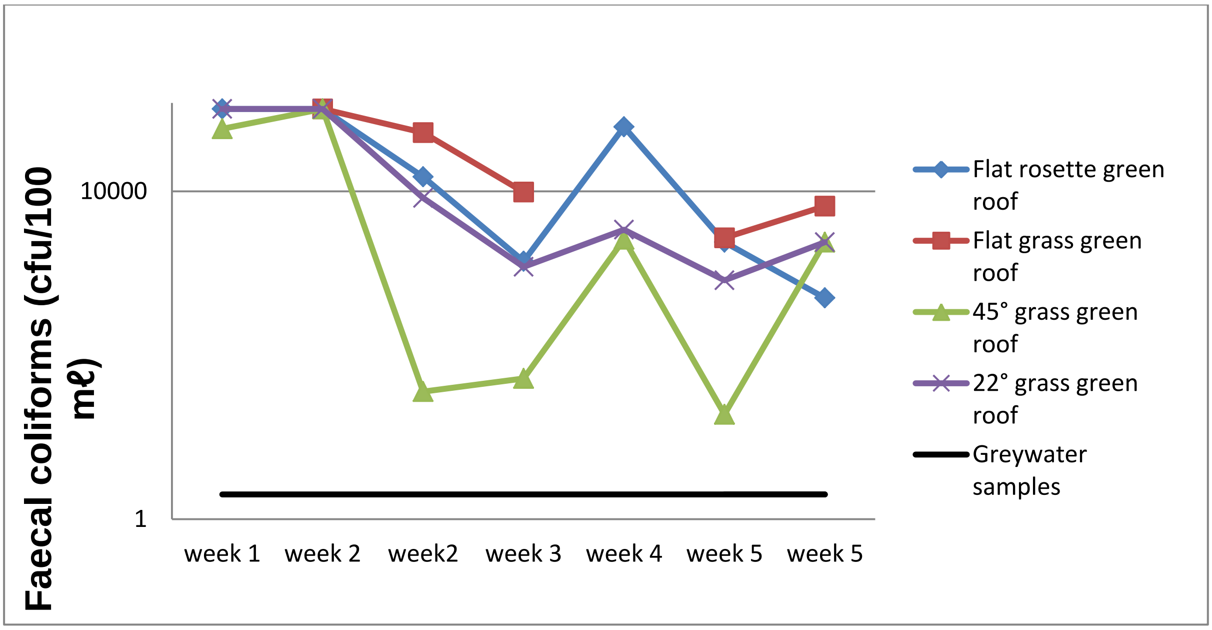

Figure 7: Faecal coliform levels (cfu/100 mℓ) of greywater runoff samples collected from four greenroofs, with typical greywater faecal coliform level included for comparison.

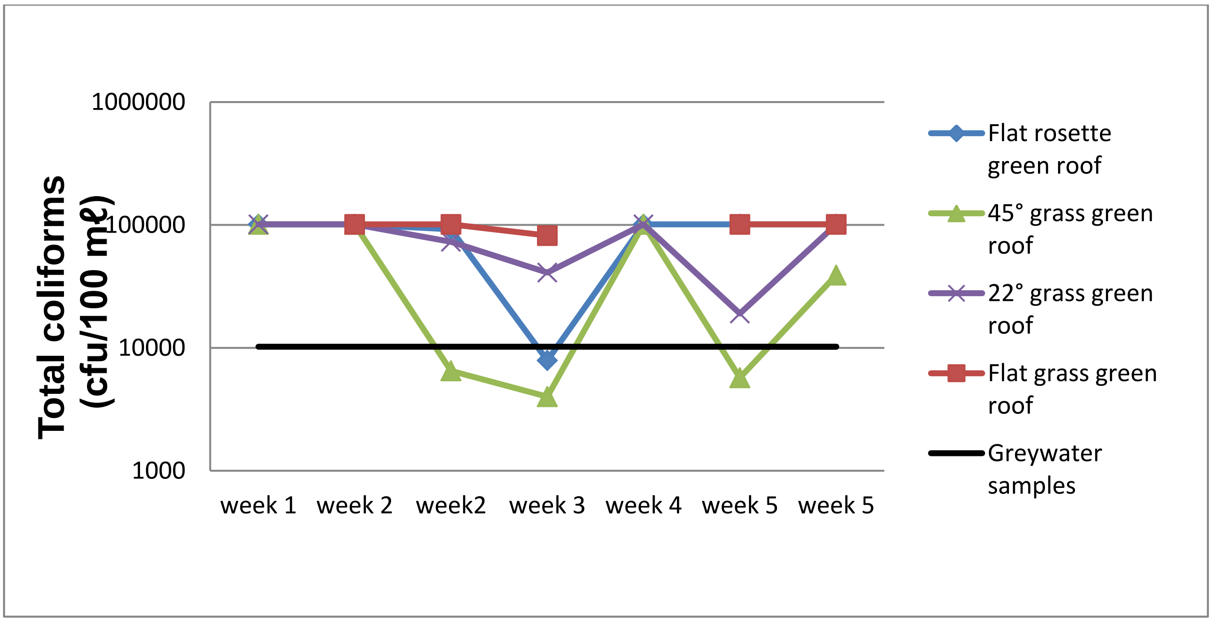

Figure 8: Total coliform levels (cfu/100 mℓ) of greywater runoff samples collected from four greenroofs, with typical greywater total coliform level included for comparison.

As with the E.Coli and faecal coliform results, there is no improvement in the total coliform levels and levels are far greater than the WRC (1998) total coliforms guidelines. Rather, there is an increase in these levels after passing through the greenroof systems. The current research mentioned above will also apply to the total coliform levels.

In general, the conclusions that can be drawn from the microbiological levels is that there is something within the greenroof set-up that is contributing to these levels, which is supported by Moran *et al*. (2004). Further research needs to be undertaken to determine what this contributing factor might be and whether there is still a chance of the greenroof acting as a natural wetland/filter for greywater.

Moving forward

Apart from the abovementioned greenroof flushing research, the Water research Group at the University of Johannesburg has undertaken various other projects to tackle the role of greenroofs at a small-scale level (residential scenario), what the effects are on a greenroof under different rainfall intensity scenarios, and even the use of a greenroof irrigated with greywater for the small-scale production of various animal feeds.

At a time when water is surely becoming a scarce commodity on a national level and, therefore, alternative water sources are becoming more popular and more research-worthy, the Water Research Group is continuing to try and improve the understanding of both greywater reuse and greenroof uses in an attempt to provide realistic solutions to impending problems.

References

Baloyi, M.K. (2014) Effect of Roof Inclination on Attenuation and Retention Ability in Green Roofs. B.Eng. thesis, University of Johannesburg.

Borchers, B., Chow, C., Doelp, M., Ent, L., Hakes, R., Heo, C., Hunsley, K., Sinha, S., Swaim, C. and Whittaker, A. (2015) Evaluating the Feasibility of Implementing a Green Roof Retrofit on Pitched Residential Roofs. Gemstone Program Thesis, University of Maryland.

Gouveia, B.D.A. (2013) The Use of Greywater in Agriculture: Effects of Storage Time. B.Eng project, UJ.

Ilemobade, A.A., Olanrewaju, O.O. and Griffioen, M.L. (2013) Greywater reuse for toilet flushing at a university academic and residential building. *Water SA* **39** (3). WISA 2012 Special Edition.

Jacobs, H.E. and Van Staden, S.J. (2008) Direct On-Site Grey Water Reuse – An Illicit or Illustrious Option? *11th Biennial Conference of the Water Institute of Southern Africa: The Confluence of the Water Industry*, 18-22 May 2008, Sun City Hotel & Convention Centre, South Africa, WISA08-038, 16p.

Malatji, P.K. (2014) An investigation into the effect of flora on attenuation and retention ability of green roof. B.Eng. thesis, University of Johannesburg.

Moran, A., Hunt, D.B. and Jennings, D.G. (2004) A North Carolina field study to evaluate greenroof runoff quantity, runoff quality and plant growth. Portland: North Carolina State University, Department of Biological and Agricultural Engineering.
Natha, 2015
Padiachy, J. (2014) The effect of green roofs on improving the quality of greywater, in terms of its nitrogen, phosphorous and microbiological determinants. B.Eng. thesis, University of Johannesburg.
South African Bureau of Standards (2011) Drinking water – Part 1: Microbial, physical, aesthetic and chemical determinants. Pretoria, SABS (SANS 241-1:2011).
Van der Walt, C.S. (2013) The feasibility of green roof growth media in the reduction of stormwater run-off and improvement of greywater quality. B.Eng. thesis, University of Johannesburg.
Van der Walt, J.T. (2012) Development of a sustainability index for South African dwellings incorporating green roofs, rainwater harvesting and greywater re-use. M.Sc. (Eng) thesis, University of Stellenbosch.
Water Research Commission (1998) Quality of Domestic Supplies -Volume 1: Assessment Guide. 2nd Edition. Report TT 101/98. Water Research Commission, Pretoria.